Report:

Water extraction, transpiration and drought resistance of tropical forage grasses under greenhouse and field conditions

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RESEARCH PROGRAM ON Livestock

Alliance

Water extraction, transpiration and drought resistance of tropical forage grasses under greenhouse and field conditions

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Highlight

- Canopy temperature depression is a surrogate for transpiration and root size under limiting water-conditions in tropical forage grasses. Its high throughput makes it a candidate for its use in large numbers of plants for selection of plants with high effective water use (i.e., water spender plants) under short term droughts conditions or high water-use efficiency (i.e., water-saver plants) under long term droughts

Rationale

Previous research has shown the need to identify grasses with high effective water use (i.e. water spenders, plants that extract available soil water to sustain greater productivity under water-limiting conditions) or high water use efficiency (i.e., water-savers, plants that save water at expense of growth). This information is needed to targeting forage grasses to different environments with different precipitation patterns. To do so, there is a need to identify root and shoot traits that are associated with effective water use (e.g., deep rooting, high transpiration) or water use efficiency (restriction of transpiration). For this purpose, we established different experiments under greenhouse and field conditions with several tropical forage grasses to identify traits and responses associated with mode of water use, and, to identify easy to perform measurements for screening purposes on many genotypes.

1. Genotypic differences in root development, water extraction and transpiration efficiency

The purpose of this trial was to evaluate genotypic differences in root development, water extraction and transpiration efficiency under two types of soil (Oxisol and Molisol) and two irrigation conditions (soil maintained in field capacity) and progressive drought for four weeks under greenhouse conditions in accessions of *Megathyrsus maximus* (CIAT 6799, CIAT 6962), *Urochloa humidicola* (cv. Tully), *U. brizantha* (CIAT 26124, cv. Piata), *Urochloa hybrids* (cvv. Mulato 2 and Cobra), *Cenchurs purpureus* (ILCA 10097) and *Chloris gayana* (ILCA 645). These data are useful to disaggregate the existing balance between water uptake by roots in soil under limited water conditions, and the water lost by the aerial part during transpiration.
Oxisol, collected in Santander de Quilichao, had an apparent density of 1.4 g / cm^3, volumetric water content at field capacity of 0.24 m^3 / m^3 and 0.07 m^3 / m^3 at a permanent wilting point. Mollisol, collected in Palmira, had an apparent density of 1.1 g / cm^3, volumetric water content at field capacity of 0.51 m^3 / m3 and 0.29 m^3 / m^3 at a point of permanent wilting. Plants were grown in columns of soil (120 cm high x 7.5 cm diameter). The design was a completely randomized block with 4 repetitions and 4 treatments.

Key results

	Progressive drought (28 days)							
	Volumetric water content (m^3/m^3)		Root elongation rate (mm d^{-1})		Maximum rooting depth (mm)		Threshold for transpirable soil water*	
Genotype	Oxisol	Mollisol	Oxisol	Mollisol	Oxisol	Mollisol	Oxisol	Mollisol
U. humidicola cv. Tully	0.14	0.35	35	30	1200	1200	0.3	0.3
M. maximus CIAT 6799	0.12	0.41	37	27	1200	1005	0.4	0.3
M. maximus CIAT 6962	0.10	0.37	43	30	1200	1151	0.5	0.4
U. brizantha CIAT 26124	0.14	0.32	28	28	1200	1110	0.3	0.3
U. brizantha cv. Piata	0.13	0.30	27	25	1200	912	0.3	0.3
U. hybrid cv. Cobra	0.14	0.43	20	18	1200	975	0.4	0.3
U. hvbrid cv. Mulato II	0.13	0.36	25	23	1200	1000	0.3	0.2
C. purpureus ILCA 10097	0.15	0.41	32	20	1200	700	0.2	0.1
C. gayana ILCA 645	0.12	0.32	30	29	1200	1200	0.3	0.3

*, Values 0 to 1. Higher values represent higher rates of perspiration.

In general, the importance of a deep root system was observed in all genotypes, to extract as much water as possible in the lower profiles of the soil. In particular, *U. maximus* 6962 showed a deep root system that allowed the extraction of all the available water to maintain its growth under conditions of progressive drought when grown in an Oxisol soil. In general, growth under Mollisol soil (soil with high clay content) affected root development (measured as elongation and maximum depth), particularly in *M. maximus* (CIAT 6799 and 6962), *U.* hybrid cv. Cobra, *C. purpureus* (ILCA 10097). *Urochloa humidicola* cv. Tully and *C. gayana* ILCA 645 were the genotypes that behaved similarly in both soils. It is of interest to mention that these two genotypes develop aerenchyma in roots (this attribute is constitutive in *U. humidicola*, and apparently in *C. gayana*), which allows the roots to penetrate deep into soils with a high amount of fine particles as clay (the case of Mollisol soil).

2. Daily evapotranspiration rates

The objective of this study was to test genotypic differences in evapotranspiration and canopy temperature depression. This information is useful for the selection of genotypes according to the potential demand for water in different environments, and for calculating crop coefficients (k), according to specific evapotranspiration values from different sites. Evaporanspiration (ET) calculations were based on data collected with porometers; in at least 3 repetitions; in plants that had a leaf area index of between 2 and 3 under field conditions in wet (March, April, May) and dry season (June, July, August) in CIAT, Palmira (Mollisol soil as described above). The average precipitation in the dry season was 3.9 mm day^{-1} and in the dry season it was 1.4 day^{-1}. Temperature in canopy and air were collected with an infrared thermometer and a wet-bulb thermometer to calculate the Canopy temperature depression index (CTD = canopy temperature - air temperature). This index provides an idea of whether the plants are stressed by lack of water (lower values, more stress; higher values, greater transpiration and access to water) or whether the plants are minimizing water loss by stomatal control.

Overall, all genotypes (except for *M. maximus* CIAT 6799 and CIAT 6962 and *U. brizantha* CIAT 26124) did not consume more water than they had available (based only on precipitation). In particular, *M. maximus* CIAT 6799 and 6962 did not show greater stress (in terms of CTD) than the rest of genotypes in the summer (despite consuming more water than all the rest). This indicates the importance of minimizing water loss (as shown by CTD) to save water for later to maintain growth or tissue water status.

Key results

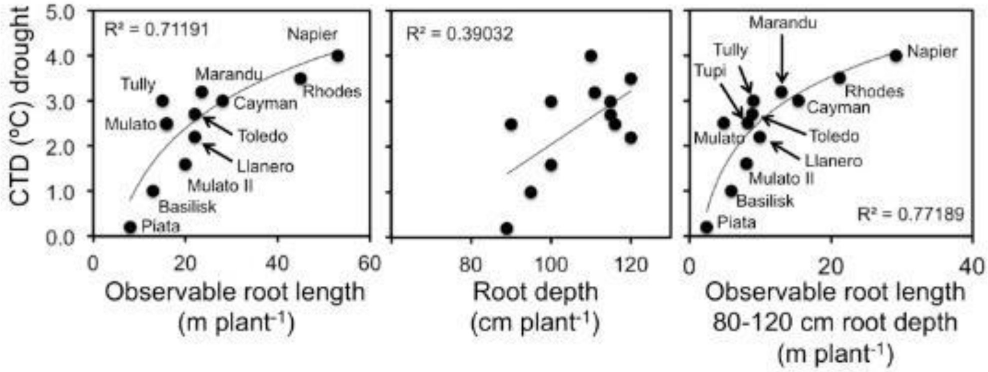
		Average ET mm day^{-1}					CTD	
Genotype	*n*	Wet	Dry	ET total mm (sum of two seasons)	Total precipitation mm (two seasons)	Water balance	Wet	Dry
U. humidicola cv. Tully	20	2.5	2.2	423	486	63	3	2
M. maximus CIAT 6799	30	4.5	3.0	675	486	-189	4	2
M. maximus CIAT 6962	30	5.8	3.3	819	486	-333	4	2
U. brizantha CIAT 26124	22	3.2	2.7	531	486	-45	3	2
U. brizantha cv. Piata	20	3.3	2.4	477	486	9	2	2
U. hybrid cv. Cobra	15	2.0	1.4	306	486	180	1	0.5
U. hvbrid cv. Mulato II	20	3.1	2.6	477	486	9	3	2
C. purpureus ILCA 10097	12	1.7	1.3	270	486	216	2	2
C. gayana ILCA 645	16	2.9	2.4	477	486	9	3	2
Bare soil	30	1.2	1.1				-	-

3. Relationship between root length and canopy temperature

The root system development is a major determinant to maintain water uptake under drying soil. Measurements of leaf and canopy temperatures are widely used to estimate access to water by deep roots. Furthermore, canopy temperatures can be used as a proxy for stomatal aperture/closure. An experiment using transparent soil cylinders inserted into PVC pipes was conducted under greenhouse conditions to test the relationship between canopy temperatures and root growth over a period of three weeks under progressive soil drying conditions. Soil used was an Oxisol (as described above). Ten *Urochloa* cultivars widely used for livestock production in the tropics (*Urochloaa brizantha* cvv. Piata, Toledo and Marandu*; U. humidicola* cvv. Tully, Tupi and Llanero; *U. decumbens* cv. Basilisk: *U.* hybrids cvv. Mulato, Mulato II and Caymán) and two other tropical grasses (*Cenchrus purpureus* and *Chloris gayana*) were used in this study. RGB pictures of the entire soil column (120 cm height x 20 cm width) were taken together with measurements of canopy temperatures at weekly intervals. The transparent plastic cylinders allowed recording of growth and distribution of roots across the soil profile. Root length at different soil profiles was estimated with digital images and ImageJ.

Key results

Grasses with greater root lengths and increased root length density at depth showed cooler canopies under drought conditions (higher values of CTD).



Acknowledgements

This work was conducted as part of the CGIAR Research Program on Livestock and is supported by contributors to the CGIAR Trust Fund. CGIAR is a global research partnership for a food-secure future. Its science is carried out by 15 Research Centers in close collaboration with hundreds of partners across the globe